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ABSTRACT

A systems model for the design and management of instruction in occupational fields is described. The model is broken down into these phases: (1) analysis, in which occupational tasks are specified via task analysis, tasks are restated as behavioral objectives and a sequence is specified for the objectives, (2) synthesis, in which instructional activities are specified and evaluative procedures designed, and (3) operation, in which instructional activities are carried out and evaluative data is collected. Feedback and iteration follow these phases wherein the data collected during the operations phase is fed back into the analysis so that it can be tested, validated, and redesigned based on input data. Each phase is briefly described, and illustrations augment the descriptions. Related documents are available as ED 027 438 and ED 027 440. (SB)

Incidental Report #3

A SYSTEMS MODEL FOR INSTRUCTIONAL DESIGN AND MANAGEMENT

Project No. 8-0334
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A STUDY OF CURRICULUMS FOR OCCUPATIONAL PREPARATION AND EDUCATION
(Scope Program: Phase I)

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New Brunswick, New Jersey

January, 1970

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A SYSTEMS MODEL FOR INSTRUCTIONAL DESIGN AND MANAGEMENT

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The purpose of this paper is to describe a systems model for the design and management of instruction. The model provides for certain critical features; it proceeds in a systematic fashion; it builds in the feature of relevance; it deals with measurable behaviors; and it specifies the relationship between learnings to be achieved.

The model is broken down into three phases. The first phase, called analysis, contains the following three activities in sequence: (1) specification of occupational tasks via task analysis, (2) restatement of tasks as behavioral objectives, (3) specification of a sequence for behavioral objectives (structural analysis). Following the analysis phase, the synthesis phase is undertaken. This phase involves two activities occurring in parallel: (1) specification of instructional activities, and (2) design of evaluative procedures. The final phase of operation includes two simultaneous activities: (1) carrying out of instructional activities, and (2) the collection of evaluative data. Following these three phases comes a fourth activity, a feedback and iteration wherein the data collected during the phase of operations is fed back into the analysis so that it can be tested, validated, and redesigned based on input data. This redesign based on feedback is then followed through to its completion from that point. This model is shown diagrammatically in Figure 1.

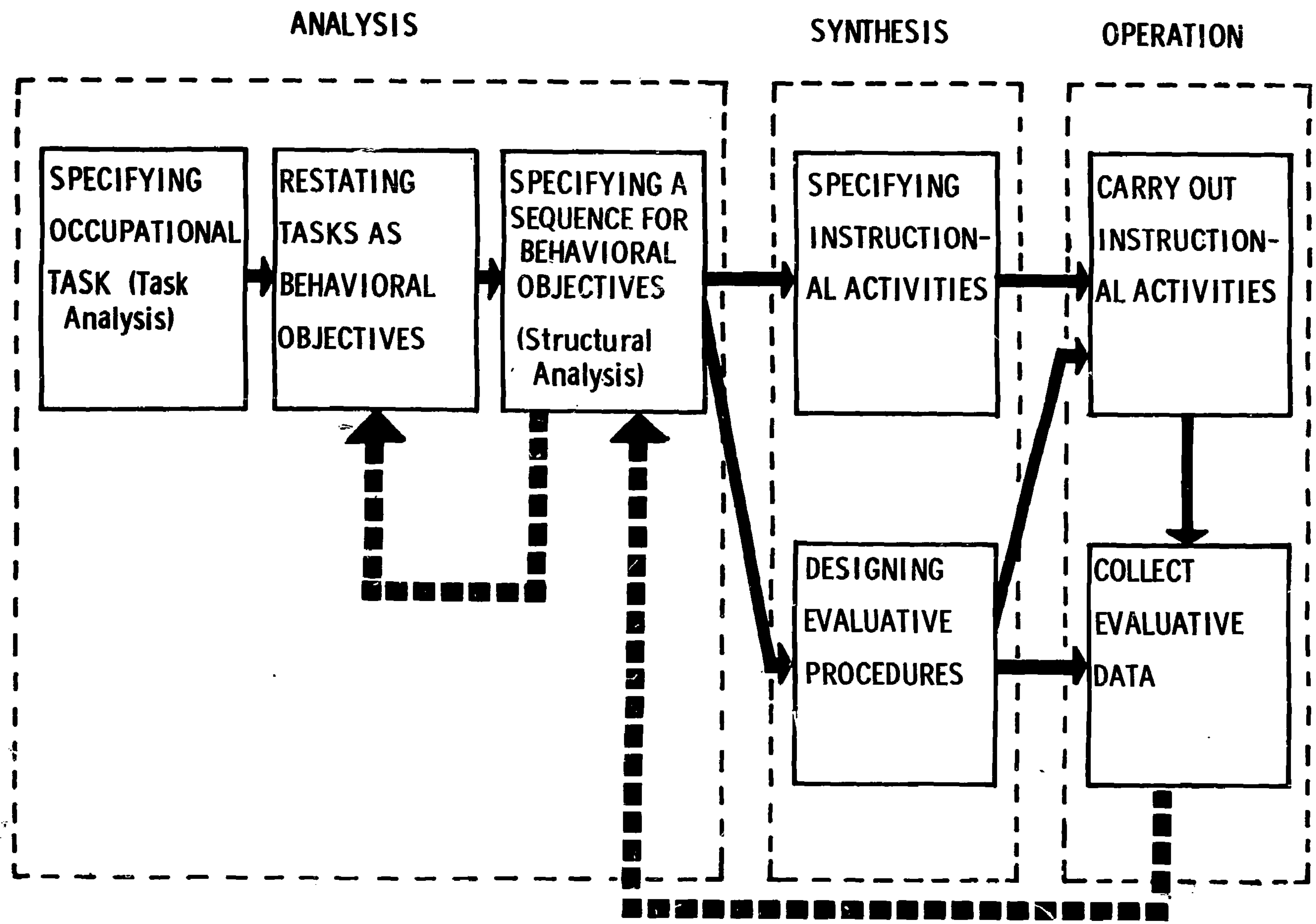
Within this paper each activity will be described briefly. Since some of these activities have already been specified in detail in other writings, the purpose here will simply be to refer the reader to these other writings. In cases where less detailed writing has been generated, descriptions will include a greater amount of detail.

1. The Specification of Tasks Via Task Analysis

Task analysis is a procedure by which behavioral out-

FIGURE 1

A SYSTEMS MODEL FOR INSTRUCTIONAL MANAGEMENT



comes that are desired are specified in the form of tasks. That is, some final behavioral capacity is analyzed into a series of those tasks that make it up. Task analysis has been most heavily employed in the vocational or occupational field. Here if one chooses to consider an occupation such as an electronics technician, one would take this occupation and attempt to specify the tasks that an electronics technician is to perform. Similarly, if one wanted to conduct a task analysis of the occupation of secretary, one would take the occupation and analyze it into the tasks that make it up. A task analysis of the secretarial occupation might include such tasks as typing a letter, taking messages, preparing and organizing reports, taking dictation from live stenographic material, a dictating machine or tape, etc.

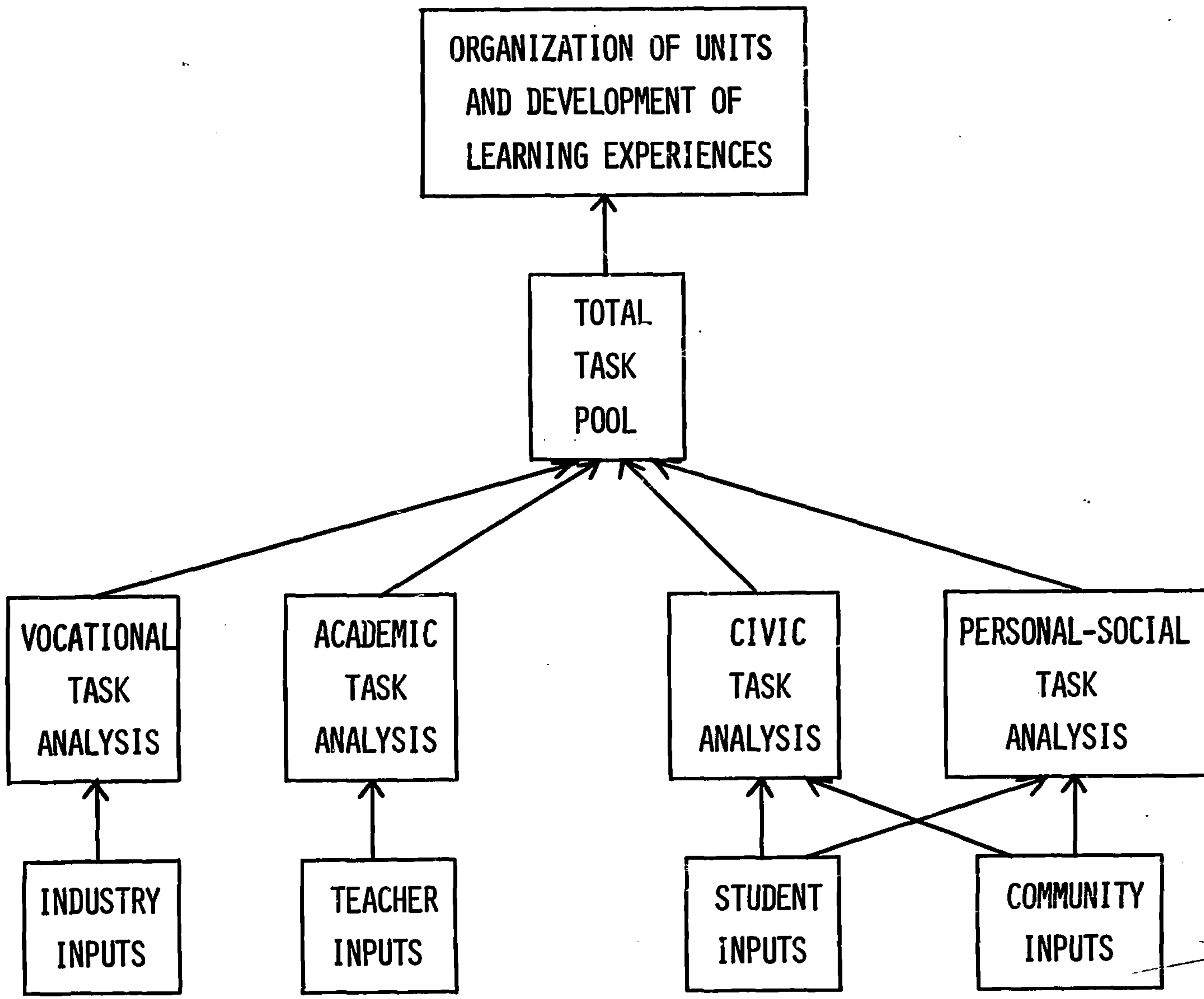
Through the use of such a task analysis, one is able to describe the full range of activities that go to make up an occupation. In further considering the occupation of a secretary, one would be likely to enunciate tasks dealing with interpersonal relations such as greeting visitors and reflecting the image of the organization, etc.

Before instruction in this or any other occupation can begin, it is helpful if not necessary to have attained an enunciation of each of the tasks which, when taken together, comprise the requirements of the occupation. While task analysis has been traditionally associated with occupations, there is no reason that it cannot be used as a point of departure for instructional material development in any learning area. One can examine academic tasks which represent the goals of an academic education. One can include such things as performance in algebra including solving quadratic equations, adding algebraic matrices, etc., as well as performance in social studies such as stating the chronology of the battles of the civil war, contrasting events in terms of their effect on subsequent crises, etc. This kind of task analysis would culminate in a long list of tasks which represent general activities to be mastered within the total academic experience.

If one is concerned with the development of interdisciplinary instructional materials, then one must draw from a wide range of areas and identify the tasks within each area. This approach is shown in Figure 2. As the figure shows, task analyses using a variety of different inputs would be undertaken in the vocational, academic,

FIGURE 2

A MODEL FOR DEVELOPING AN INTERDISCIPLINARY CURRICULUM



civic, and personal-social areas. Each analysis would culminate in the specification of tasks or performances which are required in each area of function and which have been deemed appropriate as an end point, or entry point, in moving into an area in which instruction is seen to function as a prerequisite.

Task analysis is seen as an activity which is to be undertaken and completed by experts in the fields in which tasks are being identified. Thus, if one were to attempt a task analysis of the vocation of electronic technician, then one would call upon individuals who are functioning as electronic technicians, those who are supervising electronic technicians, and those who are training electronic technicians in order to specify the tasks included in that occupation. If one were interested in providing skills in the areas of civics and citizenship, then one would call on individuals from the community representing community organizations, political organizations, and students themselves in order to generate the tasks which might be deemed appropriate in defining the range of behavior of a citizen.

The notion that one begins in the design of instruction by specifying the tasks that are to be achieved as the goal of instruction represents a departure from the typical techniques used for curriculum development. However, if instruction is seen as a route toward some goal and that goal is the performance of a wide range of tasks, then it is useful to attempt to identify those tasks in advance so that instructional sequences can be developed which are aimed specifically at the attainment of those tasks. While there are models for task analysis in the vocational areas there have not been models developed in academic, civic, or personal-social areas. Thus, the use of the task analysis approach in these areas will represent an attempt to determine how such a task analysis can best proceed.

It is also entirely possible that the specification of academic, civic, and personal-social tasks will show great generalizeability from student to student, school to school, and community to community. If such is the case, it should be possible subsequent to the specification of tasks in these areas for schools and communities and students to examine a list of tasks in each area and to specify those that are useful for its purposes. Thus, the use of task analysis and the prespecification of tasks that define an area of interest or activity may provide a highly efficient route to allow for the individualization of goals on both the level of the student, the school, and the community. Freedom to select is difficult to implement if there is not a suitable specification of alternatives. To the extent that task analysis provides for an extensive delineation of alternative tasks to be attained, it may provide a highly useful vehicle for students, and for program developers in specifying the goals to result from a series of learning experiences. To the extent that students make the choice, they are in a position to uniquely individualize their own educational experience.

2. The Restatement of Tasks as Behavioral Objectives

Much has been written about writing and using behavioral objectives. The use of behavioral objectives has become increasingly widespread throughout the academic world. In fact, there are now organizations that collect or "bank" such behavioral objectives and catalog them, thus making them available for use in any school system desiring them. In addition, much inservice training has been afforded to teachers in the writing of behavioral objectives. However, the role of behavioral objectives in the instructional design and management process has not been clearly spelled out. The purpose of the discussion here is to better specify the place of behavioral objectives in the total sequence of instructional design.

As can be seen from the model shown in Figure 1, behavioral objectives represent neither the beginning nor the end, but merely a step en route from the starting point to an ending point. By arbitrarily taking the instructional activity that presently constitutes a curriculum and attempting to enunciate behavioral objectives which describe that instruction, one may be acting to improve the potential of that instruction and the evaluation of performance as a by-product of that instruction. But one is not of necessity making that instruction more relevant. In order to achieve relevance one must begin by specifying the tasks to be performed by students at the completion of instruction. This is accomplished through the use of a task analysis. Such task analyses provide statements of goals or end points that are not arbitrary to the instruction being developed, but are rather quite meaningful and relevant in terms of students and their needs. However, in order for tasks identified through task analysis to be suitable building blocks for a systematic curriculum design, it is necessary to put them in a form where they can be used for sequencing, instructional materials design, and evaluation. It has been found that the behavioral objective is a useful rendition of the goal statement for the above purposes. Thus, the second step in the process is characterized by an attempt to take the task specified in the task analysis in the first step and to restate these tasks in the form of behavioral objectives.

A behavioral objective, as has been said many times, includes a statement of performance — typically using an action verb, a statement of the conditions under which the performance is to occur, and a statement of the criteria against which the performance is to be evaluated.* By the systematic use of performance language as well as the specification of conditions and criteria, the behavioral objective becomes a useful device for subsequent steps in the systematic approach. However, it is again emphasized that the arbitrary selection of instructional material which is then converted to behavioral objectives is not consistent with the total philosophy of this approach.

In order for the approach recommended here to be followed, curriculum designers must begin with a specification of the tasks or goals of their instruction. This task list, so constructed, then becomes the basis for the construction of behavioral objectives. Thus behavioral objectives are not simply derived from existing instruction or snapped out of the air. They are systematically evolved from statements of tasks which are relevant to and descriptive of the goals of learning. Once behavioral objectives have been written based on these tasks it then becomes possible to move on to the third step in the process.

*The mechanics of writing behavioral objectives have been set forth in various sources including Mager (1962) and Tuckman (1967).

3. <u>Specification of a Sequence for Behavioral Objectives (Structural Analysis)</u>

Structural analysis, as has been described in detail by Tuckman (1968), is a technique for specifying the sequential relationship among behavioral objectives. This process is shown in its simplest form in Figure 3. With regard to learning activity as specified by a behavioral objective as a terminal point, one can ask three questions, i.e., (1) what competencies can a learner achieve only after prior achievement of the one in question, (2) what competencies must a learner have already achieved in order to achieve the one in question, and finally, (3) what competencies are reasonably independent of, and therefore can be taught concomintantly to, the one in question.

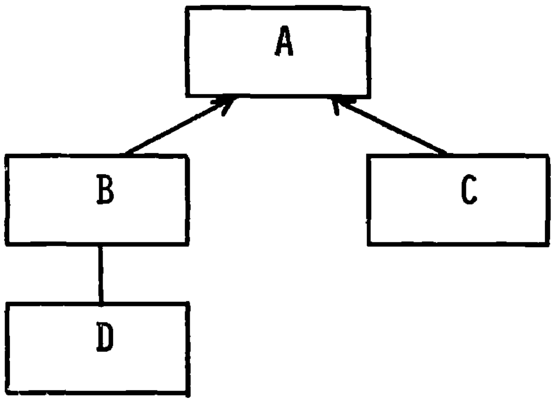
Through the use of this approach, it becomes possible to specify a sequence of instructional objectives which, when put together in the order specified, should maximize movement from entry into instruction to the attainment of some final goal.

The activity of structural analysis is predicated upon the supposition that learning is a sequential process featuring the operation of contingent relationships among the competencies, skills, and concepts to be mastered. The establishment of an appropriate sequence, moreover, is one of the essential conditions of learning. The purpose of structural analysis is to attempt to establish, on an <u>a priori</u> or hypothetical basis, the contingencies that exist between the competencies to be acquired. This analysis provides the instructional designer or manager with a map to follow in setting forth the order of instructional activities to maximize the probability that each activity will be successful. The instructional manager can then attempt to identify the prerequisites for any set of competencies, with the former serving, in turn, as prerequisites for higher order competencies. Without this approach, behavioral objectives must be sequenced on some more haphazard and less systematic basis. Ideally, therefore, one would proceed from the restatement of tasks as behavioral objectives to the specification of an order in which these behavioral objectives are to be covered within instruction, this activity being termed structural analysis.

Structural analysis is also highly useful within the

FIGURE 3

SPECIFYING A SEQUENCE FOR BEHAVIORAL OBJECTIVES



FOR EXAMPLE:

(1) WHAT ACTIVITIES MUST THIS ACTIVITY PRECEDE?
FOR B, IT MUST PRECEDE A.

(2) WHAT ACTIVITIES MUST PRECEDE THIS ACTIVITY?
FOR B, D MUST PRECEDE IT.

(3) WHAT ACTIVITIES CAN OCCUR CONCOMITANTLY (I.E., ARE PARALLEL)?
FOR B, C IS PARALLEL.

evaluation process because it provides, as will be described later, a model or system into which evaluative data can be fed in order to have something specific to evaluate. It provides the vehicle by which individual performance data can be used to assess and improve the instructional process. This aspect and benefit of the structure or sequence as set forth in this step will be elaborated upon later under the heading of Feedback and Iteration.

4. Specification of Instructional Activities

The instructional manager is now ready to generate and specify instructional activities. He has already produced a thorough-going analysis of the goals as tasks, as behavioral objectives, and as behavioral objectives located in a sequence with their relationships of one to the other specified. The task remains to design instructional activities which will be aimed at the achievement of these sequenced behavioral objectives. At this point a wide variety of possibilities exist, none of which will be gone into in any degree of detail. It will suffice to simply mention the fact that instructional activity should require some action or participation on the part of the learner and it should take advantage of multiple instructional alternatives utilizing the full range of media and technology available; that it should prescribe individual or small group activities where teachers represent one of many instructional resources, and that finally and perhaps more importantly, the specification of these instructional activities should be given to the students directly rather than mediated via the teacher. That is, the teacher, or manager, or designer, should develop a specification of instructional activities including setting forth textbook pages to be read, other resource books to be examined, films to be watched, audio tapes to be listened to, laboratory experiments to be carried out, shop activities to be carried out, teachers to be spoken to, classmates to be spoken to, etc., and that this series of instructional activities relevant to the achievement of an objective should be given to the student so that he can then, at his own speed and in his own way, go about carrying out the activities in order to guarantee his own competence. Needless to say, this activity must include within it the opportunity for evaluation not only of the student, but of the instructional process and the instructional materials. This leads to the next step, which should be carried out at the same time that instructional materials and activities are being produced, i.e., designing evaluative procedures.

5. Designing Evaluative Procedures

Three types or bases for evaluation are appropriate for discussion here, although again, none of the three will be dealt with in detail. The first important function for evaluation is to evaluate the performance of each individual student as a basis for making decisions about his further progression in a particular sequence or movement on to other sequences. Individually-oriented instruction based on a systems model described herein requires reasonably constant monitoring or student performance and instructional prescriptions based on the level of this performance. In order to accomplish this, reasonably frequent evaluations must be carried out. Thus, evaluative procedures and materials must be developed in conjunction with the development of instructional activities based on the very same behavioral objectives and structural analysis that preceeded the development of instructional activities and upon which it was based.

The second function for evaluation has been called formative evaluation. Formative evaluation represents an attempt to evaluate the behavioral objectives and their sequencing in order to provide the possibility of improvement in the instructional package. Formative evaluation is an ongoing evaluation which occurs as part of the development process and allows for data to be fed back into the development process in order to improve the materials as they are being developed. Formative evaluation procedures and their relation to structural analysis and behavioral objectives has been set forth in detail in Tuckman (1967).

Finally, a third evaluative function has been called summative evaluation, and that is the overall evaluation of a final instructional package by comparing it with alternative packages. Such evaluation does not occur during the development of instructional materials but typically occurs subsequent to their development and refinement. Thus, at some point during the development process one must begin to think in terms of summative evaluation but this will more profitably occur late in the developmental process as opposed to early. The design of summative evaluation procedures has been described in considerable detail in Tuckman (1969).

Overall, the process of designing evaluative procedures entails the examination of each behavioral objective incorporated into the sequence and the development of a measurement activity to determine whether the goal as set forth behaviorally in the behavioral objective statement has been attained by the student. Thus, in designing evaluative procedures one attempts not only to measure the success or failure in performance of the terminal objective but to determine relative success and failure of each subordinate or enabling objective which exists in the structure and has been identified as a prerequisite of a terminal objective. By measuring performance on each sub-objective and the terminal objective, one is able to accomplish all three kinds of evaluation essentially at the same time.

Once behavioral objectives have been formulated and structural analysis has been completed, the task of designing evaluation procedures is simplified greatly. One need only examine the structure and for each behavioral objective in it generate a performance measure or two. Such performance measures are easily generated since one of the characteristics of behavioral objectives is that they are written in such a form, i.e., behaviorally, that they easily may be transformed into measurement instruments. Popham, in his behavioral objective bank printouts, provides not only behavioral objectives but sample measurement items as well. This is done because of the intimate relationship between such measurement items and the behavioral objectives from which they have been derived.

Thus, the task of designing evaluative procedures for either formative or summative program evaluation or for the evaluation of student progress is a reasonably simple and straightforward task using the procedures recommended in this paper.

At this point the total synthesis process has been carried on and one is ready for the stage of operations.

6. Carrying out Instructional Activities

Little need be said about this step in the process, for it is the reasonably obvious one wherein the instruction as set forth in Step 4 is now carried out. Since the sequence of instruction has already been determined and the materials or activities which have been designed to provide the instruction have already been set forth, the process of carrying out instruction is simply to make the instructional activities available to students in the order which has been prespecified.

7. Collecting Evaluative Data

This activity within the stage of operations, occurring concomitantly to the implementation of instruction, is a reasonably straightforward one. That is, what is entailed is simply applying the evaluative procedures that have been designed in Step 5 to the actual collection of data during the course of instruction. Typically, this takes the form of automatically administering "end-of-unit" or "end-of-sequence" tests by which individual performance on terminal and enabling objectives is measured. This step may also entail measurement of attitudes and interests at various points along the way, or actual observations of behavior. However, evaluation simply follows the procedures which have been established and thus becomes an integral part of the total instructional process.

The more completely evaluative procedures have been designed and programmed into the overall instructional process, the easier, more complete, and more useful will be the process of collecting evaluative data. Most important within this data will be assessments of performance on the terminal objective and each enabling objective, making it possible to determine if a particular competency or skill has been mastered.

8. Feedback and Iteration

The step of feedback and iteration is a critical and distinctive feature of the systems model proposed herein. One of the shortcomings of most instruction as it presently occurs is that the results of the instructional process are not systematically collected nor fed back to the designers of instruction in order that these results can be used to modify instructional activities and their sequencing. That is to say, instruction as we see it today is not self-improving. This is most unfortunate because student performance, as has been suggested above, provides a basis for evaluation not only of the student and his learning capacity, but of the instructional material and program itself. It is uncommon to see the results of student performance pooled across students used as a basis for systematic refinement of instructional activity. Yet, the sum total of students' performance reflects not only their own capacities and attention but on the nature and efficacy of the instructional program as well.

Thus, while students are evaluated by examining their individual performance, programs can be evaluated by examining data pooled across all students who have had the program. This information, however, can only be used to its greatest effect if some system for the specification of instruction is used to which this data can be related in some meaningful way. The model proposed here has incorporated this feature.

One of the critical hypotheses made in generating the instruction within this system is the sequence specification characterized by a multiplicity of hypotheses about the contingency relationships between behavioral objectives. This can be seen by referring again to Figure 3. Figure 3 reflects a number of hypotheses. The first hypotheses that Figure 3 reflects is "A cannot be mastered unless mastery of B and C precede it." A second hypothesis is that "The mastery of B and C can occur simultaneously." A third hypothesis is that "Mastery of B requires mastery of D as a precursor," and finally that "Mastery of C has no identifiable precursor."

Each of these hypotheses can be tested with reference to the data which has been collected. If we have systematically measured in the preceeding step the ability of students to perform A, B, C, and D, we can then determine (for example) whether the majority of students who are able to perform B have already mastered D. We can, in fact, describe four possible outcomes that may occur when one examines the performance of B and D. (These are shown in Figure 4.) We may find, for instance, as we have hypothesized, that individuals who are performing B are also performing D and vice versa. Another possibility is that individuals may succeed in performing D but not B which is not contradictory to the hypothesis, but leads us to suspect that other prerequisites to B may exist, or that instruction attempting to move students from B to D is insufficient. It is also possible that students may succeed on neither B nor D, a finding which is consistent with the hypothesis, but

FIGURE 4

POSSIBLE CONTINGENCY OUTCOMES AND THEIR IMPLICATION FOR INSTRUCTIONAL DESIGN

Outcome on superorindate*	Outcome on subordinate	Implication for hypothesis	Recommendation for design
correct (+)	correct (+)	support	no change
incorrect (-)	correct (+)	support	look for missing b.o.** improve instruction on super.
incorrect (-)	incorrect (-)	support	look for missing b.o. improve instruction on sub. & super.
correct (+)	incorrect (-)	refute	change sequence

*Superordinate might be B in Figure 3 while subordinate would be D.
**b.o.≡ behavioral objective; super ≡ superordinate; sub.≡ subordinate

certainly not a happy one. It would suggest the improvement of instruction for both B and D. The fourth possibility clearly contradicts our hypothesis. That is, the possibility that students may fail on D but succeed on B provides evidence for the refutation of the hypothesis that D is a prerequisite for B. To the extent that performance data support this last possibility to a greater extent than the preceeding three, the instrument designer is encouraged to reevaluate and subsequently alter the structure which he has decided upon on an a priori basis. Such an alteration in terms of the example given would be to reconsider the relationship between B and D.

Many alternatives can be considered in the light of this data. If other alternatives occur frequently enough, instructional designers will be encouraged not necessarily to alter the order of the instruction, but perhaps to examine the components of the sequence to identify a behavioral objective that has been overlooked or to improve the instructional activities themselves in order to increase the likelihood that movement from lower to higher levels in the structure will be possible.

The characteristic of using performance data describing small bits of student performance and pooling this data across students to examine the structure of the instructional material as prespecified and to alter instruction in accordance with this data is an important and perhaps unique characteristic of this model (as opposed to non-systems oriented models).* Thus, the model provides for the systematic use of feedback as an aid to instructional design.

Iteration prescribes that instructional activity will be carried out again; that is the process will be reiterated or repeated. It will not be repeated, however, until evaluative data has been used to alter the total list of behavioral objectives, the sequence of these objectives, and/or the instructional activities for attaining these objectives in accordance with the evaluative data which has been fed back into the model. When this has occurred, a somewhat altered series of instructional activities sequenced

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*The reader is encouraged to examine the work of Walbesser (1969) which describes the uses of this feedback in a more systematic and detailed fashion than has been attempted here. Discussions of this point may also be found in Tuckman (1968).

in perhaps a different way than had been originally hypothesized, and featuring perhaps more, perhaps fewer behavioral objectives than originally will be made available to students. Admittedly, this repetition of instruction will occur during the next year or semester for a different group of students who will hopefully bear great similarity to those on whom the first iteration or trial is carried out. In the iteration, the second group of students will experience the instructional activities, evaluation data will be collected based on their performance, and this data in turn will be fed back into the model. The second trial, or iteration, will then provide for a second testing and refinement of the sequence as prespecified. It is expected that the structure will stand up better the second time around than it did the first. At this point it is conceivable that a third iteration can take place. Every time the instructional materials are used, it can serve as iteration or trial from which data can be obtained to use for modifying the instruction. A point will be reached when the designers will feel that the model and the design have been refined to a point beyond which no further improvements are likely. At this point, the instructional activity is ready for summative evaluation.

* * * * *

The overall purpose of this paper has been to deal briefly with the elements of a systematic model for designing and managing instruction. Considerably more detail would be useful in terms of each of the activities within the model. In addition, little has been said about the manner in which data are to be stored, analyzed and retrieved for large numbers of students as would be required if such a model were to be used to design instruction for regular school systems. The reader is referred to various systems of computer-managed instruction which are used for managing, storing, retrieving, and utilizing large amounts of data as would be necessitated by the use of this approach.*

What has been attempted in this paper is to deal most saliently with the major characteristics of the model, i.e.,

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*The New York Institute of Technology and the IPI Project at the University of Pittsburgh Learning R&D Center are two sources of information on CMI.

the fact that it begins with task analysis rather than with the statement of behavioral objectives, that the statement of behavioral objectives follows, and is in turn followed by a step in which these objectives are sequenced, that instructional design is ultimately followed by the operation of the program and the collection of data, and that this data is then fed back into the original design so that it can be modified on a basis of its success and/or failure. This last characteristic may be the most useful and critical feature of the model.

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